SF Stillaguamish Vegetation Project EA – Soil Report

MOUNT BAKER-SNOQUALMIE NATIONAL FOREST

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1. Applicable Laws, Regulations, and Policies

The National Forest Management Act (NFMA, 16 U.S.C. 1604) states, "…timber [shall be] harvested from National Forest System lands...only where soil, slope, or other watershed conditions will not be irreversibly damaged." Forest Plans will "insure…evaluation of the effects of each management system to the end that it will not produce substantial and permanent impairment of the productivity of the land."

2. Relevant Standards and Guidelines

Disturbance thresholds that define where long term impairments can result are defined in the Region 6 Watershed Protection and Management Manual (USDA 1998). Whenmanagement activities may not meetsoil objectives and standards, rehabilitation may be necessary.

The Forest Service Manual for Region 6 requires Forest managers to plan and conduct land management activities so that new activities do not exceed detrimental soil conditions on more than 20 percent of an activity area (FSM R6 Supplement 2500.98-1, chapter 2520). For the South Fork Stillaguamish River(SFSR) project, the "activity unit" is represented by the treatment unit for reference. Impacts to productivity are measured according to soil disturbance criteria including compaction, soil displacement, puddling (rutting) and severe burning. Direction on minimum effective cover after ground disturbing management actions, and direction to rehabilitate sites is also included in the R6 Supplement.

The FSM R6 Supplement emphasizes maintaining soil quality through the adequate retention of organic material, both coarse wood (3 inch or greater diameter) and fine wood litter (less than 3 inch diameter). In addition, the supplement specifies to either maintain or restore soil moisture regimes, including subsurface flows, to maintain soil quality.

Standards and guidelines that directly address soil productivity and soil stability are not found in the Northwest Forest Plan (USDA and USDI 1994), but are addressed in the

Mount Baker-Snoqualmie National Forest (MBS NF) Forest Plan. Onegoal of the MBS NF Forest Plan is to maintain or enhance soil and land productivity (USDA 1990, p. IV-117).Nutrient capital on forest and rangelands is to be maintained at acceptable levels. The forest plan gauges productivity levels using indications of soil disturbance, directing management to minimize soil productivity impairments caused by compaction, displacement, puddling, severe burning, and soil loss from surface erosion and mass wasting.

The MBS NF Forest Plan includes Management Objectives directing the Forest to “Plan and conduct land management activities so that reductions of soil productivity caused by detrimental compaction [and] displacement…are minimized” and “so that soil loss from surface erosion and mass wasting, caused by these activities, will not result in an unacceptable reduction in soil productivity and water quality”. In the MBS NF Forest Plan, the hazards from steep unstable slopes are also recognized as needing special consideration at the project level (USDA 1998), specifically stating that “Areas classified as irreversible soils (S-8) will generally be considered as unavailable for road construction and timber harvest”.

3. Management Requirements and Mitigation Measures

The following management requirements and mitigations measures were included in the Proposed Action to assure compliance with relevant management direction and provide protection of soil and water quality:

- Best Management Practices.
- Avoidance of wetlands and unstable areas.
- Upgrading ofroads, hiking trails and trailheads to reduce sediment contributions to the watershed, and provide safe recreation opportunities.
- Where ground-based logging systems are used, felling is to be accomplished in a single pass of equipment.
- Skid roads are to be approved by the sale administrator and equipment is to travel on operationally generated slash as much as possible to minimize soil disturbance and compaction.
- Existing skid roads and trails should be used where possible.
- Reconstruction and maintenance of system, non-system, and temp roads.
- Activity fuels within the stands would not be treated.

- Revegetation of areas of bare soil where designated.

- Re-opening 28.7 miles of closed system roads, temporarily re-opening 12.2 miles of existing non-system temp roads and 15.9 miles of old roads identified from LiDAR, and creating 1.5 miles of new temp roads.

- Decommissioning approximately 11 miles of National Forest System road no longer needed for forest management (currently non-drivable).

- SWF16 – Areas of gouging or soil displacement on steep slopes resulting from yarding systems will be treated to prevent rill and gully erosion and possible sediment delivery to stream courses. Erosion control treatments may include, but are not limited to: repositioning displaced soil to re-contour disturbed sites; creating small ditches or diversions to redirect surface water movement; installation of coir logs along slope contours; and scattering slash material to create flow disruption and surface soil stability. These measures will be in place prior to expected seasonal periods of precipitation or runoff, and kept current during and outside of Normal Operating Season (NOS).

- SWF18 – Ground-based log transport equipment is restricted to sustained slopes that are no greater than 35 percent. Non-yarding ground-based equipment is restricted to sustained slopes less than 50 percent.

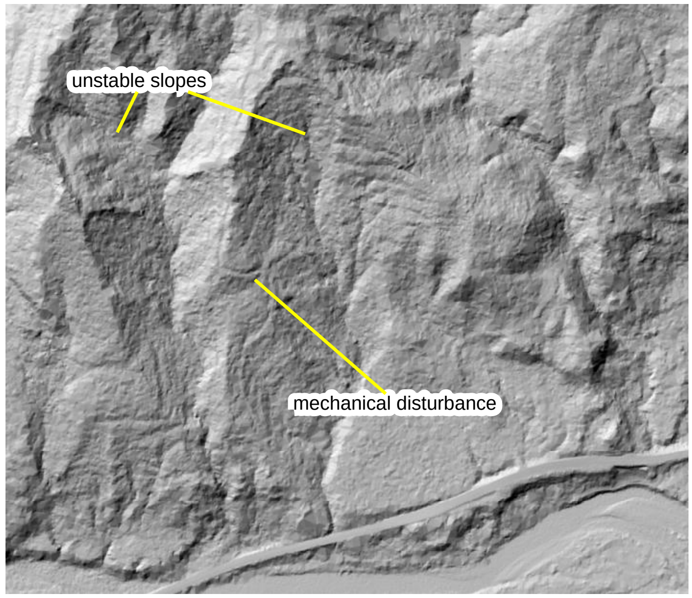
- SWF19 – Comprehensive list of mitigations for ground-based yarding.

- SWF33 – Roadbeds of decommissioned and obliterated roads would be reclaimed to resist erosion, improve subsurface hydrology, improve regrowth, and deter motorized traffic.

4. Analysis Methodology and Assumptions

Areas described as S-8(prone to landslide or mass wasting activity) have been identified within the analysis area. Unstable soil areas were initially identified in a 1981 analysis and labeled as S-8 soils where considered “irreversibly” damaged from either severe mass wasting hazards or recent landslide events. These mapped soils were field surveyed, along with additional soils recently identified using LiDAR. Those areas verified as unstable were removed from management consideration during project planning.

Prior to field work, the project Soil Scientist conducted an extensive review of LiDAR imagery to determine where potential soil mass movements may be occurring or have occurred, and to assess the magnitude of existing detrimental disturbance (see figure at right of Eldredge Creek area).



Once familiar with the project area, the SFSR project area was visited from August 27th-30th, 2016, by the project Soil Scientist and Hydrologist.Planned timber harvest units, landforms, and proposed road work were investigated for soil and water limitations. Unitswere walked through to verify assumptions made during LiDAR review,understand the limitations of the project, and to characterize site properties necessary for landscape and management interpretations.

Concerns from both the public and Forest Service employees were used to direct the analysis in addition to Forest Service guidance. Using this feedback and after field reconnaissance, three measurement indicators were used to investigate effects from the project:

- Soil disturbance
- Mass wasting risk
- Soil cover

Soil productivity impacts were analyzed using the soil disturbance indicators outlined in the Region 6 soil guidelines and the Forest Plan standards. Sample areas were identified on the ground to verify whether a disturbance seen in LiDAR was a detrimental disturbance according to the R6 soil guidelines.The objective is to minimize the extent of soil disturbance to ensure no permanent soil impairment and to retain soil on the slope as required by the National Forest Management Act (1976). Using soil disturbance criteria, the 20 percent detrimental soil disturbance threshold indicates potential impairment to soil productivity (FSM R6 Supplement 2500.98-1, chapter 2520). The soils analysis requires use of an area to evaluate percentage impact. Typically, analysis compares disturbance on a harvest unit basis.

The Region 6 FS Manual for Watershed Protection and Management directs National Forests to plan land management activities so that the soil moisture regime remains unchanged (FSM R6 Supplement 2500.98-1, chapter 2520). Management induced effects to the water table or subsurface flow changes on plant growth and potential community composition were evaluated using soil properties, field reconnaissance and knowledge of hillslope drainage.

5. Affected Environment

The physical setting of the SFSR project is dominated by the glacial trough valleys of Canyon Creek and the Stillaguamish River. The slopes drop 4,000 feet from Mt. Stillaguamish to the Stillaguamish River (elevation range from 1000 feet to 5,000 feet). The south side has a series of steep river valleys with steep mountain slopes rising over 2,000 feetin elevation.Along the Stillaguamish River, footslopes spread out gently onto alluvial terraces that border the primary floodplains. A contiguous forest persists across the bottomlands and up the slopes, thinning around talus, bedrock outcrops, and avalanche paths. The SFSR project plans to treat forests within the bottomlands and along the valley footslopes and backslopes.

The project area lies primarily within a metamorphic zone of schists and gneiss associated with mountain building episodes of the Cascade Range (Tabor *et al.* 2000). These metamorphic rocks tend to be resistant and stable, although glaciation left much of the project area very steep. Generally soils are shallow, but the mainstem SFSR valley contains large glacially-associated valley-filling deposits, generally lacustrine (lake) clays underlying glacial-fluvial outwash. These were created by (a) rivers draining Cascade glaciers depositing poorly-sorted gravel, sand and silt in areas where rivers gradient and velocity decreased, and (b) tongues of glacial ice periodically blocking this outwash and creating dams, where thick (up to 50 feet or more) layers of clay and fine silt were deposited (Miller and Sias, 1997).

Permeability is a key aspect of these glacial deposits, which comprise the majority of permeable valley floor and footslope sediments. They permit rapid infiltration and groundwater movement and lack cohesion. Lacustrine deposits and till are the most widespread low-permeability sediments, and locally control groundwater flow. Seeps and springs tend to be concentrated where highly permeable outwash material overlies low-permeability lacustrine sediment; these sites are also closely associated with landsliding and other forms of mass wasting. On hillsides, a similar setting is commonly found where young, permeable soils overlayunweathered glacial till or bedrock (Booth *et al.* 2003).

Advanced soil development, where it occurs in the project area, is the result of abundant moisture and landform stabilitywhich have allowed time for mineralization. Steep mountain terrain is prone to landslides that can prevent soil development. Thus, over-steepened slopes (35 to 45 degrees) remain in a state of perpetual adjustment, including most of the upper slopes along the northern valley sideslopes. Footslopes accumulate colluvial material from debris flows and soil creep, but remain somewhat stable for soil formation. Soils develop quickly even in areas of landslide deposits, since the physical churning advances the weathering and subsequent soil development (Wells 1988).

The combination of abundant moisture, well drained slope material, and conifer vegetationdevelopspodosol soils. Water decomposes mineralsin the topsoil and leaches them either into the subsoil or into groundwater. In the subsoil, leached iron and aluminum accumulates and forms humiccomplexes. The resulting mineral composition produces very acidic conditions. Soil survey data indicates soil pH ranges from 4.8 to 5.6 (NRCS 2013). This type of soil environment somewhat resists decay where thick humic forest floors form in excess of 10 cm thick.

A dramatic and tragic example of glacial outwash instability was the 2014 Oso Landslide, which claimed 43 lives as it spread across approximately one square mile along the North Fork of the Stillaguamish River (NFSR) four miles east of the town of Oso. The Oso Landslide was actually a re-activation of a feature called the Hazel Landslide, which has been intermittently active since at least 1937 (Miller, 1999; Keaton *et al.* 2014). The material mobilized by the Hazel Landslide consists of a deep (160 feet) layer of sand underlain by lacustrine silt and glacial till along the margin of Whitman Bench, a remnant of a large glacial outwash terrace. This and other terraces along the western perimeter of the Cascades were formed as the Cordilleran Ice Sheet moved south into the Puget Lowland, damming this and other mountain valleys and forming lakes. Sediment washed down from higher elevations settled in the lake bottoms, forming a low-permeability layer of clay and silt. When the sand portion of a deposit has very little clay or "fines" to cement it together, it is structurally weak. Such an area is also sensitive to water accumulation, increasing internal "pore" pressure. Water infiltrating from the surface accumulates atop the less permeable clay and till, where it form a zone of weakness. Under the right circumstances, this situation can lead to slope failure. In case of the Oso Landslide, as well as a smaller 1967 event at the same location, the river had migrated laterally and undercut the base of the slope, further destabilizing the hillside.

A similar situation exists along the SFSR across from the Gold Basin Campground. The Gold Basin Landslide Complex (GBLC) is a naturally-occurring, intermittently mobile complex consisting of three distinct drainages or lobes that have been active since at least 1942. Unlike the Hazel Landslide, each lobe of the GBLC consists of poorly-sorted sand and gravel alternating with layers of high-plasticity silt and clay. The upslope edge of each lobe consists of a distinct headwall. The river is actively incising the base of each lobe, which in turn drives repeated small-scale mass wasting events (McCabe, 2016). Benda and Collins (1992) calculated that the GBLC contributes approximately 40,000 tons of sediment per year into the SFSR, which is about 25% of the river's annual sediment yield; Perkins and Collins (1997) estimated that the overall subbasin within which the GBLC is situated supplies up to 88% of the SFSR sediment load. This complex appears to be unstable largely due to (a) steep slopes, (b) the complex consisting of poorly-sorted glacial outwash and glaciolacustrine material, (c) the presence of impermeable clay-rich layers that cause perched groundwater and soil saturation, (d) a lack of vegetation to stabilize the slope and intercept precipitation, and (e) continuous removal of fines from the base of the slope by the river (McCabe, 2016). There is no direct evidence of human activity causing any increase in the rate or degree of mass wasting at this site. Benda and Collins (1992) note that the upstream lobe (Lobe 1) expanded eastward following clear-cut harvesting of timber upslope of that area; however, the middle lobe (Lobe 2) also expanded substantially at that time, with no changes in upslope vegetation. As Shelmerdine and Boehne (2004) concluded,

> The management link to slope instability at the site is minor at best, and if there is one it has yet to be established with certainty. Current movement is associated with the combination of conditions related go groundwater movement, geologic materials (the stratigraphy, or sequence of sand, gravel, silt, and clay layers) forming the bluff, and the steepness of the slope (p. 3).

Such conditions have created a series of landslide complexes on both sides of the NFSR and SFSR valleys; the Washington Department of Transportation (2015 found 22 landslide deposits along a seven-mile stretch of the NFSR valley, including the Oso slide and other lobes of the Hazel slide.In the NFSR valley, these zones tend to be fairly stable—either remaining largely in place or moving gradually via creep—unless a stream or roadcut undermines the toe or a lower portion of the slope (Miller, 1999). The SFSRvalley, on the other hand, has no features similar to Whitman Bench (large alluvial or colluvial benches with oversteepened, undercut slopes) within or near any proposed treatment stands.

Climate

The maritime moisture and moderate soil temperaturessupport robust conifer growth. For the most part, these montane forests growing on the west side Cascades have a limited growing season due to seasonal low temperatures, despite abundant moisture (Littell*et al*. 2010). As such, the growing season is marked by the minimum annual temperature, and soil temperature regimes correlate to patterns of vegetation growth and species distribution. Forest species and growth rates decrease as one moves from the highly productive bottomlands and footslopes up to the hillslopes and ridges. The project area has a frigid temperature regime, with mid to upper elevations transitioning to colder cryic soils. Frigid areas experience substantially more soil warming during summer. Using PRISM data, the project annual minimum temperatures ranged from 38 degrees F along the valley margins to 35 degrees F along the upper reaches of the planned treatment area (Daly *et al*. 2008).

Annual precipitation ranges from 97 to 141inches (WDNR 2012), with much of the winter precipitation as a rain/snow mix. Using station data from Cedar Lake, the annual distribution ranges from an average of 21 inches during the wettest month (November) to just 3 inches during the driest month (July)(WRCC 2015).

Project soils

Soil processes are the culmination of abiotic factors in addition to work of organisms both above and below ground. The rhizosphere is an intense nexus of biological activity and represents a relationship between plants, soil, and soil organisms (Clapperton 2006). In these conifer forests, nutrient allocation for trees relies on mutualistic relationships with mycorrhizae species and production from soil microbes. All conifers have obligate relationships with ectomycorrhizae.Much of the availability of the limiting nutrients for these forest ecosystems, which are nitrogen and phosphorus, derives from soil microbes. The temperate humid climate provides adequate moisture for soil processes year round; however, cold temperatures during most of the year constrain soil microbial action. The mineralization activity by these organisms drops substantially when temperatures drop below 50 degrees F (Davidson *et al*. 1998). From spring through fall, temperatures warm enough to maintain a growing season that ranges from 120 to 155 days (NRCS 2013).

The Soil Resource Inventory(Snyder, 1970) was used to describe soils and soil characteristics. A current correlated soil survey does not exist for the MBS, so no soil series was named for the forest. There are soil 52 units mapped within the activity units; however, only soils with greater than 100 acres in aggregate are listed in Table 1 to illustrate the general properties of the area soils.

The dominant soil types are derived from parent materials of glacial lacustrine, glacial till, and residuum from metamorphic rocks. The soil textures tend to be loams and silt loams, which tend to be more prone to compaction than sandy or clayey soils.

Soil organic matter/Soil cover

Due to the highly leached conditions, organic matter provides a substantial nutrient base for these forests. Organic matter exists primarily as duff and litter that overlies a leached horizon, although humics may also accumulate lower in the soil profile in these spodic soils. Production of conifer leaf litter, branches, and woody debris account for the main organic matter onto the forest floor while root decay provides soil organic matter deeper in the solum. Although conifers were the predominant lifeform, addition organic matter inputs were derived from understory plants and alder. Large alder groves were found near riparian areas, talus, and breaks in the forest canopy caused by roads. Understory growth was highly variable depending stand openness and aspect. In general, stands supported understory vegetation as the stand density decreased.

Because of the productivity of the project stands and the infill of understory vegetation and regenerating conifers, both soil cover and soil organic matter were adequate to excessive throughout the project area. No bare ground was evident in those stands visited, and duff layers ranged from 2 to 25 cm thick. In stands near the upper end of duff thickness, understory vegetation is limited to surface bryophytes and fungus.

In addition to the fine duff illustrated in the photo above, coarse woody material is also generally in excess of what is considered necessary for soil productivity. Excess fine and coarse wood can accumulate, further suppressing understory vegetation and adding fuel loads that would cause high soil burn severity during even moderate severity wildfires.Excess coarse and fine woody material was prevalent in previously clear-cut stands due to cull logs and windthrow.

Disturbance history and soil instability

The Washington State Department of Natural Resources (WDNR, 2011) defines four types of mass wasting that commonly occur on Washington’s forested slopes: shallow-rapid landslides, debris torrents, large-persistent deep-seated failures, and small-sporadic deep-seated failures.

Shallow-rapid landslides (also known as debris slides) commonly occur on steep slopes where shallow soil overlies more cohesive material (e.g., bedrock or hardened clay). They typically occur in convergent areas where topography concentrates subsurface drainage. As the slide moves downslope, it often breaks apart to form a debris avalanche, whichmay deliver sediment to streams and damage roads. An area’s susceptibility tothese slides is affected by slope steepness, soil saturation, and loss of root strength. Forest management activities can increase shallow-rapid landslide occurrence by altering these conditions; however, even after clear-cutting, only a small portion (typically a few percent or less) of the landscape actually fails following timber harvest (WDNR, 2011).

A debris torrent (or debris flow) contains a highly mobile slurry of soil, rock, vegetation and water (up to 30%) that can travel miles from its point of initiation, typically in steep, confined mountain channels. Debris torrents form when all or part of a landslide liquefies during failure. Debris torrents can contribute sediment locally at the site of deposition and also downstream, increasing fine sediments in spawning gravels.

Deep-seated landslides occur in response to geologic weakness or channel incision, and may be triggered by strong earthquakes or climate—includingruns of several wet years or individual large storm events. The failure plane is below the soil (colluvial) layer and commonly cuts through two or more strata. Debris is typically supplied from the margins of the feature to a channel. The stream itself can be the cause of chronic movement, if it periodically excavates the toe of a large slide mass. The Oso slide consisted of a deep-seated landslide that turned into a debris torrent at its distal edges.

Small-sporadic deep-seated landslides are slumps that can be triggered at irregular time intervals (by storms or earth movement). Because movement of these failures is at least partly hydrologically controlled, land use can influence movement in certain situations.

The existing primary source of sediment within the project area comes from slope instability. Two sources of slope instability were found within the project area: landslides and road failures. Past logging practices may have destabilized old landslide features in some areas, and road cuts generate instability particularly where stream channels cross the road prism.

The project plans to treat second growth from timber primarily harvested over the last century; theseincluded commercial clear-cutsof old growth trees from the 1940s to the 1960s, and non-commercial cuts in the 1970s and 1980s.The complete removal of large established trees likely caused instability on soils prone to landslides (S-8 soils). DeGraff (1979) and Schmidt *et al*. (2001) discuss at length the importance of the rooting structure in stabilizing soils in wet environments. It is also clear from Schmidt *et al*. that the larger the size of the roots, the more stability is offered to the soil. In those stands that are regenerating from past management, the roots have high density and have by now become interlocked, particularly in the hemlock stands, offering increased soil stability. As these stands mature, the roots would grow thicker and become increasingly interlocked.

In those areas where the over story has been removed, the large, interlocked roots of the large trees have died and rotted in the moist soils. This is consistent with findings from Schmidt *et al*. (2001) whereby conversion of old-growth, unharvested forests to industrial forests should trigger significant increases in the rates of landsliding. Soil stability was compromised and likely contributed to the initiation of the slides observed during our field observations. In those active slides, subsurface water flow has been interrupted and has surfaced around or within the slide. This surface flow keeps the soil wet and contributes to the instability. Those observed slides continue to exhibit movement. The photo on the right shows recent tree fall situated on a sliding block of soil that is terminating in a drainage. There is low risk of shallow sliding (as seen in the photo above) on soils where solid metamorphic or igneous rock forms the structural foundation on the majority of the project area.

Given the large stocks of carbon associated with soil and high growth rates, these wet forests tend to be resilient to timber extraction depending on harvest frequency and intensity(see Jandl*et al.* 2007). However, sufficient time is needed to rebuild organic matter reserves in the soil and total site carbon (Mackenzie *et al.* 2006, Jandl*et al.* 2007).For most forest types, longer rotational lengths leads to more total carbon accumulation in the forest (Harmon *et al.* 2009). This project has moderate thinning with time since last harvest averaging 75 years. Modeling of carbon accrual for similar forest types in the Pacific Northwest showed that this harvest strategy could accrue up to twice the total carbon as do normal clearing methods (Harmon *et al.* 2009).

Table 1. Major Soil Types withinSFS Project Area.

Map Unit	Soil Texture	Parent Material	Acres
617M	Loam and gravelly loam	Residium and colluvium/glacial till and drift	1960.1
037M	Loam	Glacial Till and Drift	733.4
034M	Silt loam	Glaciolacustrine deposits	715.3
061M	Gravelly loam	Residium and colluvium	588.2
036M	Loam and sandy loam	Glacial Till and Drift	569.0
031M	Loam or silt loam	Interbedded glaciolacustrine/alluvial and till deposits	381.3
018M	Loam or sandy loam	Alluvial and marginal lake deposits	363.0
023M	Loam or silt loam	Glacial Till	292.2
035M	Silt loam	Glaciolacustrine deposits	194.5
030M	Loam or silt loam	Interbedded glaciolacustrine/alluvial and till deposits	179.4
613M	Loam or silt loam	Interbedded glaciolacustrine/alluvial and till deposits	144.6
022M	Loam or silt loam	Glacial Till	130.0
032M	Loam or silt loam	Interbedded glaciolacustrine/alluvial and till deposits	125.8
358M	Loam or silt loam	Interbedded glaciolacustrine/alluvial and till deposits	118.6
038M	Gravelly loam	Glacial Till and Drift	112.0
012M	Loam	Glacial Drift	103.5
071M	Gravelly sandy loam	Residium and colluvium	103.1
076M	Gravelly silt loam or loam	Residium and Till	102.7

Another source of landslides are the many unmaintained roads in the project area. The purpose of this report is not to document the degraded transportation features that are degrading soil productivity and water quality; these are well-documented in the Hydrology and Transportation reports. However, the slope failure caused by an unmaintained logging road off of Heather Creek off Road 42 illustrates the potential magnitude of soil loss and potential water quality decline from the

unmaintained roads in the project area.

From field reconnaissance, surface soil instability was identified in the Eldredge Creek area, Schweitzer Creek (unit M2, Road 4020), and Forks of Canyon Creek area (stands G51 and G64, Road 41). These areas showed evidence of ongoing soil movement, primarily associated with shifting of glacial outwash deposits atop lacustrine soils. This movement appears to be primarily in the form of soil creep, but may have episodically moved at faster rates. Factors triggering soil movement may be a combination of (a) slope steepening as streams undermine slope toes, and (b) past land management actions, i.e., forest clearing and road construction across unstable slopes. Other areas were identified but are not located near management units. Those areas that are identified were excluded from logging activities.

6. Environmental Effects (includes Cumulative)

Public issues and internal Forest Service concerns on the project were used to guide the analysis, in addition to Forest Service staff guidance. Using this feedback and after field reconnaissance, three measurement indicators were used to investigate effects from the project:

- Soil disturbance
- Landslide hazard
- Erosion hazard

Area of Analysis. To assess soil disturbance, the direct, indirect, and cumulative effects of the projectare analyzed at the scale of the footprint of the thinning units. To assess potential soil and landslide hazard, the direct, indirect, and cumulative effects are analyzed in the context of the project area, or the hillslopes from valley bottom to ridgetop.

Soil Disturbance

The Forest Service uses soil disturbance thresholds to avoid creating long term impacts to soil productivity. Soil disturbance thresholds define levels where management actions could create long term damage to soil function, considered a detrimental disturbance. Levels are defined the Region 6 Guidelines (Forest Service Manual (FSM) R6 Supplement 2500.98-1, chapter 2520) and referenced in the Forest Plan (USDA 1990, p. IV-117). A 20percent threshold evaluated for each harvest unit provides a benchmark above which detrimental disturbance could impact long term soil productivity.

Soil disturbance criteria used to describe disturbance include soil compaction, puddling, rutting and displacement. Compaction and puddling signal changes to soil porosity that can decrease soil gas exchangeand drainage for plant and soil microbe respiration. Research has demonstrated that when soils compact to the extent that resistance exceeds 2 Megapascals (MPa) of force, not only is gas exchange is decreased but the soil density becomes root limiting (Seigel-Issem*et al.* 2005). Soil displacement affects soils by breaking soil structure and making soil particles available for erosion. The soil mixing can have the indirect effect of decreasing the organic matter available in soil. The mixing action accelerates decomposition that metabolizes otherwise stable forms of organic matter, affecting soil nutrient retention (Booth *et al.* 2006, Jiménez Esquilín*et al.* 2008).

Direct and Indirect Effects

Alternative 1 – No Action

The No Action Alternative would preclude additional soil disturbance. Stands would continue to grow, adding organic matter into soils, and decreasing residual effects from past logging disturbance.

Under the No Action Alternative, the planned road maintenance and closures would not take place. Road failures would continue to cause erosion and slope failures and, subsequently, locally reduce soil productivity. Also, sediment delivery into creeks and aquatic habitat would continue from failing road prisms.

Although speculative, the climate in the project area may become warmer and drier during the summer, thereby increasing the fire frequency. As thick overstocked stands mature, many of the poles will fall and accumulate on the forest floor. This accumulation would increase potential of high soil burn severity during a wildfire.

Alternative 2 - Action alternative

Alternative 2 would maintain soil productivity by minimizing soil disturbance below regional thresholds. The rate of soil disturbance generated depends on the type of timber extraction method. A combination of ground based and cable yarding are proposed. Ground based extraction produces high rates of disturbance when compared to skyline yarding systems. Cable yarding that either fully or partially suspends logs generates low rates of soil disturbance. Helicopter yarding fully suspends logs and thus does not disturb soils.

Cable systems would displace and compact soils primarily in the center of the skidding lanes where logs may drag along the ground on one end. Predicted detrimental disturbance from skyline yarding is 2 percent, using soil monitoring data from the Darrington Ranger District (Unpublished Internal Report, Jordani 2010). Studies report a range of 2 to 10 percent adverse soil disturbance (Clayton 1990, McIver and Star 2000), considered detrimental for this analysis. Increased disturbance occurs as the yarding lanes converge at the skyline machine and where logs only partially suspend.

Downhill skyline yarding can bare more soil than uphill skyline, since the tower has limited reach to suspend the log. However, the added disturbance does not typically exceed detrimental thresholds. For context, the pressure exerted by dragging tree boles on soil is less than the dynamic force from ground-based machine traffic. Skyline yarding produces minor direct soil impact, but does have risk for erosion due to the slope steepness.

To mitigate erosion hazard from skyline yarding, the project would use a variety of treatments includingslash, berms, repositioning displaced soil, small ditches, and installing coir logs to disperse overland water flow. Additional mitigation would limit the width of the log skid path to 15 feet and space corridors at 120 feet to reduce disturbance.

Ground based harvest and yarding of treescompacts and displaces soils, with the severest disturbance along repeat-traffic routes and at log landings. Severe soil disturbance can include rutting deeper than 12 inches which creates puddling, and total removal of the topsoil. Away from landings, logging slashthat falls during harvest activities can mitigate pressure and displacement by machine traffic. Close to the landings, the traffic clears larger swaths of organic material and topsoil and the repeat traffic generally compresses soils into detrimental conditions. Contemporary harvest practices have reduced these effects with lower pressure equipment. Historical practices skidded logs behind tractors, producing very high levels of disturbance. The ground-based systems this project plans to use would at least partially suspend logs, which lessens the gouging from skidding. The main soil disturbance results from logging equipment wheels and tracks and processing operations on and near landings.

Predicted detrimental disturbance from ground based harvest and yarding ranges from 8-15 percenton a harvest unit basis. MBS soil monitoring data from the Darrington Ranger District found roughly 7 percent of the ground-based area had moderate soil disturbance (potentially detrimental), and an overall footprint of 22 percent disturbance when including low and moderate soil disturbance (Jordani 2010). The 7 percent detrimental soil disturbance is roughly half the threshold value (15 percent) used whereby long-term reductions to tree growth may occur. These estimates include the impacts from skidding and landings construction.

The results from the soil disturbance monitoring on the Darrington District were similar to published findings from an Idaho study comparing cut-to-length and feller-buncher harvest systems. Both harvest systems resulted in a disturbance foot print of 20-25 percent areal extent across a unit (Han*et al*. 2009). However, actual rates of soil disturbance can vary highly depending on the operator efficacy, the terrain, soil wetness,and specific soil characteristics (Han*et al.* 2009, Miller *et al.* 2010, Page-Dumroese*et al.* 2010).

The project mitigates the effects of ground based yarding through prevention and post treatment measures. Preventive measures include avoiding operation on steep slopes, avoiding weather conditions that exacerbate rutting, spacing skid trails, and using a slash mat for travel off of temporary roads, and re-using existing landings and skid trails. Post logging treatmentswould facilitate soil recovery stabilizing areas against erosion on the highest impact areas including skid trails, landings and temporary roads.

Logging also increases the risk of reducing soil cover. An increase in bare ground is considered detrimental soil disturbance if it increases the magnitude of erosion and sedimentation. No bare ground was observed in the project area, with much of the area having thick enough duff layers to suppress regeneration. However, because activity fuels would not be treated and bare areas would be vegetated, there is likely to be an increase in the thickness of soil cover with very little area of bare ground exposed.

An indirect effect of logging is the increased risk for erosion. The steep slopes, combined with areduction in canopy cover, can increase the risk of erosion where bare and compact soils exist. The proposed project requires rehabilitation of disturbed areas to reduce the risk of runoff-induced erosion. This risk further declines with time as regrowth increases canopy cover, ground cover (including duff), and root interconnectedness. Areas with higher levels of disturbance would take longer to recover. The recovery time for skyline yarding corridors differs from recovery time forground based yarding travel-ways,due to the level of soil damage. Skyline corridors have a low intensity of disturbance, allowing for quick soil recovery. It is predicted that following harvest the erosion hazard would be moderate or less for the initial three years due to the resulting soil cover and mitigation measures applied to the limited extent of bare areas.

No units were found to have an extent of detrimental disturbance greater than 15%. This is primarily because most of this area was skyline logged due to the steepness of the areas. Although soilwould be compacted during activities, design criteria would limit the extent of detrimental compaction to less than 15% of each unit; including limiting the extent of activities and using active remediation (decompaction). For those areas, natural recovery would occur within two decades. Biologic activity and freeze-thaw are processes recognized to recover compacted soils, depending on the climate regime (Miller *et al*. 2010, Roche and Kimsey 2012). A northern Idaho study of long-term effects of silvicultural practices found 30 percent of compaction recovered after 24 years, even for the most severe treatment, where slash piling scalped off topsoil and all organic matter (Roche and Kimsey2012). In comparison, a soil compaction study in southern Colorado found relatively little recovery of soil compaction after 16 years (Rawinksi and

Page-Dumroese 2008). The authors reasoned that less freeze-thaw occurs within the frigid climate regime of their study. The Idaho site had a frigid regime but also had much more moisture. The ample moisture within the SFS project area and its relatively long growing season create ideal conditions for soil recovery; thus, natural recovery on soils still in place should be well within the 24 years observed at the Idaho site.

Logging Effects on Soil Stability

There has been little research on the effects of logging on soil stability in western Washington. In the most relevant study, Miller and Sias (1997) prepared and ran a geohydrologic model seeking to predict causes of potential soil instability at the Hazel Landslide site prior to the Oso Landslide event. Among their conclusions was the following:

> These results indicate that toe erosion is the primary factor initiating the spectacular, river-moving events that everyone notices. Harvest activity in the recharge area can reduce stability of these same slopes and the model predicts the type of temporal and spatial correlations observed between harvesting and accelerated landslide activity. However, the magnitude of effects of harvest on slope stability are less than those associated with bank erosion. We surmise that harvest-related reductions in stability can affect the timing and increase the size of any single failure, but that such failures would still occur in the absence of harvest solely in response to erosion of the toe (pp. 3.16-3.17).

The harvest activity simulated in the above study consisted of clear-cutting. Even less work has been done on the impacts of thinning on soil stability. Miller and Sias (1997) did not model this, but noted that transpiration rates of thinned stands are likely to be similar to untreated stands, at least during summer months. They also note that any increase in throughfall (and thus reduced precipitation interception and evaporation) caused by thinning would be at least partly offset by increased ventilation of the overstory (and thus greater evaporation; pp. 2.14-2.15). Similarly, an increase in undergrowth density triggered by thinning would increase interception during the first growing season following treatment.

The most important factor that may increase soil instability following thinning is likely to be the reduced density of roots that hold soil together and reduce the risk of shallow-rapid landslides. This is certainly a concern along steep clear-cut slopes, to the point where landslide occurrence can be predicted with some certainty along clear-cut slopes (e.g., Furbish and Rice, 1983; Burroughs, 1985); but there is less evidence for such impacts due to thinning, partly because any effects would occur years to decades after harvest as the roots slowly decompose and lose their soil-binding capability. Sidle (2005) found little difference in rooting strength due to thinning even where the thinning cycle was as short as 20 years, especially where logging operations sought to retain vigorous understory vegetation. Indeed, Sidle (2005) notes that in northern California, thinned stands may actually have lower landslide densities than unthinned stands.

Roads

The proposed action would construct 1.5 miles of new temporary road,re-open 28.7 miles of system road, and temporarily reopen12.2 miles of nonsystem road and 15.9 miles of old system roads identified from LiDAR. Assuming a maximum 20-foot disturbance width, temporary road building and reopening would degrade a maximum of 141.3 acres of soil due to clearing and excavation—most of it old road prism or ditch, or other previously disturbed soil.All roads would be properly constructed and maintained to minimize erosion and other soil instability, and minimize any alteration of streamflow patterns.

The forest service considers system roads, which includes roads in storage, as administrative sites. Thus, managing the road system roads would not degrade existing soil condition. Rather, the improvements may decrease offsite roadwash from impacting adjacent productive soils.

The project would use a number of rock sources for road building. Three rock sources would be used where prior excavation has occurred for road building and rock outcrops. The use would be administrative and results in an irretrievable loss, though currently unproductive by virtue of the rock outcropping.

The new temporary road building would result intemporary loss of the existing soil function.Reclamation, common to all alternatives, would obliterate the temporary roads which stabilizes the roadbed against erosion and reclaims the area for regrowth.

The project would also obliterate the unclassified roads after use for all alternatives. This action would lead to a net improvement over the current condition since access would decrease. Discontinuing access would allow for vegetation to take hold and advance soil recovery.

Reclamation of temporary and unclassified roads would improve soil drainage on the road prism by ripping the surface to 18 inches and/or outsloping, and would mitigate the road interference of overall hillslope drainage to the extent possible.In Idaho, ripping restored 40 percent hydrologic conductivity within 5 years (Luce 1997, Foltz and Maillard 2003). Monitoring on the Olympic NF of road decommissioning found an overall downgrade in risks from gully erosion by decreasing road-to-stream connectivity by 70 percent (Black *et al*. 2009). The application of slash and/or coarse wood debris on the reclaimed road surface provides groundcover that reduces erosion incidence in addition to an organic substrate that increases the recolonization by soil microbes.

Seeding and transplanting are additional stabilization and recolonization techniques that would be considered on a site by site basis to speed recovery.

Cumulative Effects

Activities considered that could result in cumulative impacts to soil productivity were primarily from past timber harvest. The SFS project is planned in plantations that were initiated in the 1920s to late 1960s. Fuel reduction activities outside of timber harvest were rare and had not occurred since the 1970s. Analysis for productivity impacts to soils focuses on the footprint of the proposed activities.

Ongoing activities that potentially affect site condition were from dispersed camping throughout much of the project area. The camping can compact soil and tramples vegetation. However, detrimental soil disturbance surveys found these impacts scattered and minor when considered at the unit level.

No future projects were identified that could cumulatively impair soils within the project treatment units.

The harvest methods used historically in the project area did not have the same protection measures as contemporary logging operations, but relied on skyline yarding that has less overall long-term soil damage than ground based yarding operations. The proposed thinning was analyzed for potential long term impairment when combined with persistent soil disturbance from the past timber harvest using soil disturbance indicators.

No adverse cumulative effects of soil disturbance were identified for the No Action Alternative. When considering past effects of management, existing detrimental soil disturbance was mostly not detectible. The low level of disturbance is due to past use of skyline, a long period of recovery since last harvest, and the humid maritime moisture together with resilient sandy soils. The moisture supports abundant growth that bolsters soil recovery. Two units did have some level of detrimental soil disturbance from extensive roads. Disturbance was estimated at 2 percent and 6 percent for unit 16.1 and unit 5 respectively.

These effects were combined with the direct and indirect estimates for the proposed harvest for the action alternatives to evaluate cumulative effects. Direct estimates including landing construction and estimates of skidding within the harvest units. Much of the landing construction occurs along road templates and thus had minor influence on detrimental disturbance estimates despite the concentrated impacts. Also, note that Forest Service consider system road templates as administrative uses and not managed for productive purposes (USDA 1998).

The cumulative effects analysis found all units would remain at or below the 15 percent detrimental disturbance threshold. Cumulative detrimental soil disturbance ranges from 0 to 14 percent. Thus, the soil disturbance analysis did not find that the project would permanently impair long-term soil productivity.

From a qualitative perspective, the project would have largely transitory and low impact on soil productivity given the retention of trees and the moderate period of growth since the last harvest. Thinning is primarily used across the project, although opening would be used to increase tree species diversity.

One of the key design criteria that lower impacts is the absence of broadcast burning. It is uncertain how fuel was treated in the prior timber harvest since high severity char, which indicates broadcast burning, was not found during field surveys. Given the reliance on pile burning along disturbed routes such as landings and roads, organic matter on the forest floor would largely be retained. Thus the lack of prior disturbance of the forest floor from site preparation and low disturbance from the project would conserve soil organic matter for continued soil productivity. From a total site carbon perspective, findings from Harmon *et al*. (2009) suggest that the SFS project's harvest level and time since harvest would conserve carbon and quickly rebound to pre project total carbon levels compared to treatments with larger forest clearing.

Landslide Risk

Direct, Indirect, and Cumulative Effects

The MBS regularly manages forest areas that may have a level of risk from landslides. To address this concern, a forestwide analysis identified areas where slides could occur. The analysis product is referred to the S-8 Soils Layer (Snyder and Boecksteigal 1981). In addition, the initial soil survey on the MBS identified risk on soils maps (Snyder and Wade 1970). Both products were used by the forest to identify concern areas of high risk active landslide areas in EldredgeCreek, Canyon Creek, and Schweitzer Creek areas. As stated earlier, MBS staff removed these unstable areas from consideration; as such, any continuing risk in these areaswouldnot be connected to any impacts associated with the proposed project or its alternatives.

Keaton *et al*. (2014) conducted a review of logging treatments visible in a series of aerial photographs going back to 1941 in the NFSR valley and found no correlation between slope instability and logging activity there, even in an era of relatively large-scale clearcut logging.Similarly, they found no evidence of overland flow or erosion along roads in the vicinity of the Hazel Landslide that could have contributed to the 2014 Oso Landslide.

Although the field assessment of the units in the SFSR valley did not find evidence for failure that could result from management activities in those areas already removed from consideration, it is remotely possible that there are areas that were not activated during past extensive overstory removal that have not started sliding. Removal of trees during proposed thinning could reduce the root strength temporarily and trigger minor movement; however, this minor risk would be short-term until the desired conditions to promote larger trees is realized.

As a result of the above analysis, it is the conclusion of this report that theproposed project and its alternatives would notgenerate any significant increase in the risk of landslides within or downslope of the project area. This conclusion is based on:

1) No change in the underlying geological formation;

2) Avoidance of areas identified as having unstable slopes and thus risk of soil failure—either via previous studies or site visits associated with this project;

3) Retention of stands through partial harvest – skips—which retain patches of undisturbed trees within stands;

4) Retention of the majority of large trees, which have extensive root systems;

5) Enhanced growing conditions for understory vegetation; and

6) Best management practices to minimize impacts from roads and interception of drainage flows.

The above measures address all of the relevant Snohomish County land-use restrictions noted on page 56 of the Keaton *et al*. (2014) report, as well as all of the recommendations of Keaton *et al*. (2014) listed on pages 162-3 of that report.

7. Forest Plan Consistency

All Alternatives would be consistent with the standards and guidelines for soils in the Forest Plan (USDA 1990, p. 4-117-4-118), as amended by the Northwest Forest Plan (USDA 1994).

In preparation for the project, soil stability hazard was analyzed using the S-8 soils layer and professional judgment to avoid having the project trigger surface erosion and mass wasting. In addition, thresholds for soil disturbance defined by Region 6 Supplement 2500-98-1, chapter 2520, were used to analyze potential reductions to soil productivity caused by project activities. Using these indicators and accounting for the project's specific soil properties and climate, it was determined there were no long-term risks to soil productivity. Applying detrimental disturbance criteria, the project would leave all Units with levels of detrimental soil disturbance less than 20 percent.

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